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PRELIMINARY TEST OF XBPM LOCAL FEEDBACK IN TPS

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Abstract

TPS is 3-GeV synchrotron light source which has opened for public users since September 2016 and now offers 400 mA top-up mode operation. The requirements of the long term orbit stability and orbit reproducibility after beam trip have been gradually more and more stringent and become a challenge from users' request. Furthermore, the thermal effect would be expected to be worsen after 500 mA top-up operation which should deteriorate the orbit drift. The report investigates the long-term orbit stability observed from electron BPM and X-ray BPM and also evaluates the possibility of the local XBPM feedback to improve photon beam stability.

INTRODUCTION

FOFB and RF frequency compensation have been applied to stabilize the electron orbit [1][2] in TPS to achieve beam position stability less than 10% of the beam size. Besides, to monitor the position and stability of photon beams, two-blade type X-ray beam position monitors (XBPMs) are installed in beamline frontends and beamlines. It is observed that the thermal effect would cause the mid-term orbit disturbance at the first 30 minutes after the beginning of beam stored and long-term slowly drift for the following 4~5 hours before it achieves the equilibrium, especially in the vertical plane. Besides, there are also obvious daily position change along with temperature variations and periodic 4-minutes variation consistent with injection cycle. Furthermore, insertion device (ID) gap/phase change is also significantly affect position stability where it is partly caused by deformation and resulted in BPM mechanics displacement and partly still due to thermal effect. The position drift/fluctuation seemed to be able to be controlled below several microns or even sub-micron in electron BPM. However, the errors would be amplified several times observed at the end of beamline XBPM. To improve beamline XBPM position stability, the local XBPM feedback is proposed and tested in TPS beamlines. The XBPM feedback would include straight-line BPM and beamline XBPM to monitor photon position and adjacent 2~4 correctors for actuators to minimize photon position variation. Since the local XBPM feedback would be operated together with FOFB. The interferences between both could be sometimes occasionally resulted in conflict and diverge. Therefore, an extra process to check interference status and avoid instability would be an important concerns.

PHOTON BEAM POSITION MONITOR LAYOUT AND ELECTRONICS

There are seven beamline open to users in TPS now. For each beamline, there are different types of X-ray or photon beam position monitors are used to detect the synchrotron radiation. The blade-type X-ray BPMs (XBPM) [3] is standard equipment installed at each front-end; quadrant PIN photodiode BPMs (QBPMs) [4] are adopted by few experimental end station. The layout of front-end instrumentation is shown as Fig. 1. XBPM1 is completed calibration and observed reliable for a while. However, the calibration of XBPM2 is not yet completed and it was observed that the horizontal and vertical readings of XBPM2 had serious coupling. Therefore, only XBPM1 is presented and included for feedback in this report. About acquisition electronics, three types of electronics had been used and evaluated. The first one uses the FMB Oxford F-460 to convert current to voltage and read the voltage with a NI-9220. The second type of electronics is a home-made device with a 0.5 Hz update rate. The third type is the commercial product and now our majority: Libera Photon which could provide different data flow for different purpose of analysis, including 10/25 Hz streaming, 5 kHz/578kHz waveform with trigger as well as post-mortem functionalities.

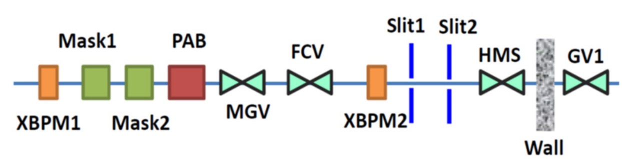

Figure 1: The layout of the front-end instrumentation.

OBSERVATION OF POSITION STABILITY FROM BPM AND XBPM

Position Drifts after Beam Restored

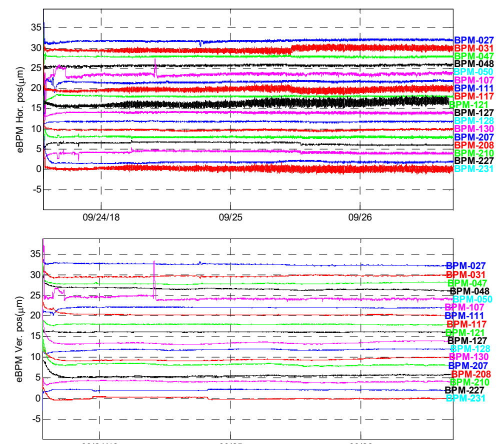

Figure 2: The upstream and downstream electron BPM reading nearby IDs for three days after beam restored.

It could be observed the upstream and downstream electron BPM nearby 7 IDs as Fig. 2 at first beginnings of beam stored, the position drift of some BPMs would be up to

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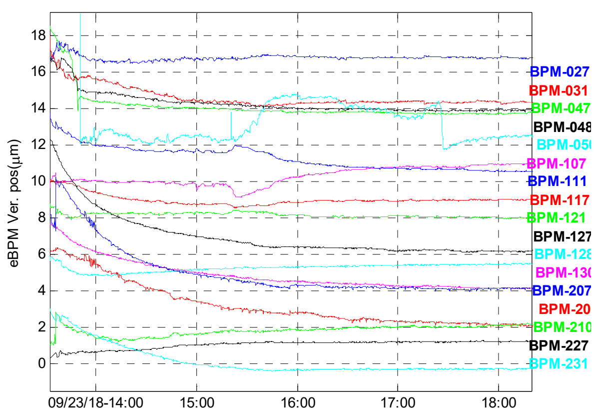
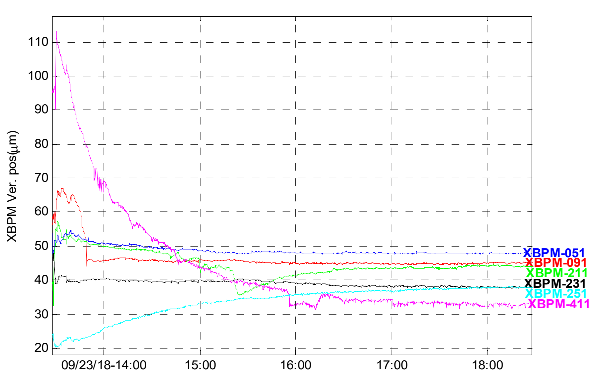
around 2~4 μm for the following 2~3 hours before it achieves an equilibrium as shown in the detail of Fig. 3(a) for the vertical plane. Then it could be remained below sub-micron. However, this 2~4 μm drift of the first 3 hours would be amplified in the beamline observed by front-end XBPM as Fig. 3(b) by 3~20 times. XBPM at the FE 41 even could up to 80 μm. This kind of drift is especially apparent in the vertical plane.



(a)



(b)

Figure 3: (a) The vertical position change of BPM nearby IDs during the first 5 hours of beam stored. (b) The vertical position change of XBPM during the first 5 hours of beam stored.

The patterns of these position distortions display quite similarly every time. But the range of the drift depends on different operational and environment condition. The major factor to affect the drift range is the time interval of the previous beam dump. Figure 4 shows the vertical position change of XBPM-41 on FE 41 and its adjacent upstream and downstream BPM during 2.5 hours from the beginnings of beam restored for Aug-21, Sep-10, Sep-23 this year. They are all operated on the standard User Mode. However, the amplitude of the XBPM and eBPM position drifts for Sep-23 (green line) is obvious 2-4 times larger than the other two. The cause is time interval (3 hours) between the beam stored is longer than the other two (0.5/1 hour). As beam dump is longer, the position drifts larger and it could take longer time to stabilize as well.

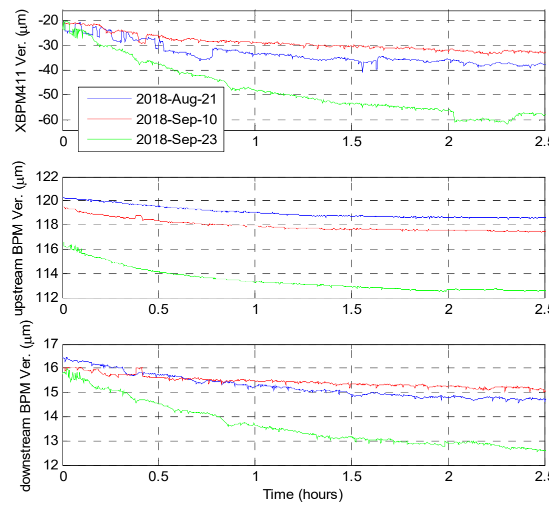


Figure 4: The vertical position change of XBPM-41 and the adjacent upstream and downstream BPM for 2.5 hours at initial beam stored.

PRELIMINARY TEST OF LOCAL XBPM FEEDBACK

From the above observation, it presents that the XBPM position drift would remain several hours and above several microns after beam restored while electron BPM could keep below few microns. Therefore, to further improve XBPM position stability, the local feedback to use XBPM is considered and proposed. Although the usage of XBPM position is quite limited when ID gap/phase change, the gap/phase has been not moving too often for most beamlines of TPS in practice and therefore the application of feedback by XBPM is feasible. This section will summarize the results of XBPM position stability improvement when applying the XBPM local feedback.

Simulating the Drifted Orbit by Changing BPM/XBPM Offset

In our preliminary test, it is found that the orbit drift as illustrated by the previous section takes long time (over 2 hours) to stabilize. Furthermore, the scale of the drift is depended majorly on the length of the previous downtime period. The more downtime, it would takes longer time to achieve the thermal equilibrium. As a result, it is a little difficult and time-wasting to compare the merits and drawbacks between different parameters or configurations. Therefore, we propose a method to change all of BPM/XBPM offsets according to themselves drift archive history to simulate the orbit drift. Figure 5 shows the results of the simulated orbit drift. The upper plot is real orbit drift where it takes two hours to stabilize. The lower plot is the simulated orbit drift caused by changing BPM offset where it simulates the orbit drift condition but the same scale of the drift takes 10 minutes.

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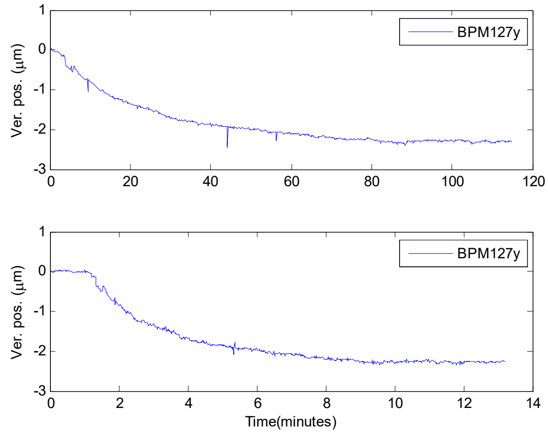

Figure 5: The upper plot is real orbit drift where it takes two hours to stabilize. The lower plot is the simulated orbit drift caused by changing BPM offset where it simulates the orbit drift condition but the same scale of the drift takes 10 minutes.

Comparison for Different PI Coefficient

Since the BPM/XBPM drift is quite very slowly, a small PI coefficient is enough. We compare the results of the different PI configurations as Fig. 6 and Fig. 7. It is shows that larger Ki would have better effect to suppress the BPM/XBPM drift while it would takes the larger strength of the correctors to achieve.

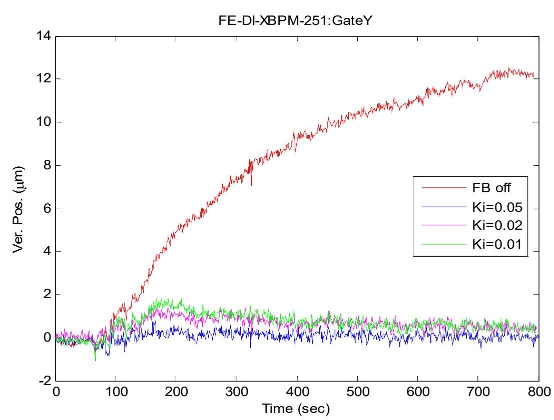

Figure 6: XBPM position drifts for different Ki coefficient.

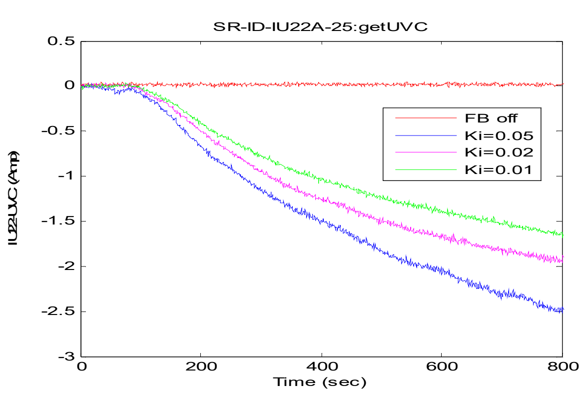

Figure 7: The corresponding corrector strength variations for different Ki coefficient of Fig. 6.

Comparison for Different BPM Weightings

The different configurations of BPM/XBPM weightings is also investigated. To acquire the minimize errors of the solutions, it could be applying different weightings to the respective BPM/XBPM. Usually, the larger weights on the critical BPM especially on the straight-line BPM would be expected to have the smaller errors. However, the results in our XBPM local feedback shows the larger weights, on the contrary, cause the larger drift errors as Fig. 8 and Fig. 9 shown. It is inferred that there are two feedback system (fast orbit feedback and XBPM local feedback) operational simultaneously so that it would interference with each other. Actually, the two feedback systems running together are not mathematically stable system when these two systems are not totally decoupled or independently. Because of the experience, we join the more procedures and the constraints to the local XBPM feedback to avoid the unstable/diverge conditions.

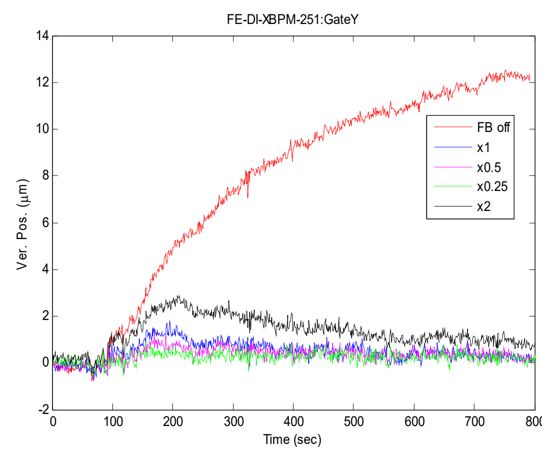

Figure 8: XBPM position drifts for different BPM weighting. When applying the larger weights, it would result in the larger drift errors but smaller corrector strength.

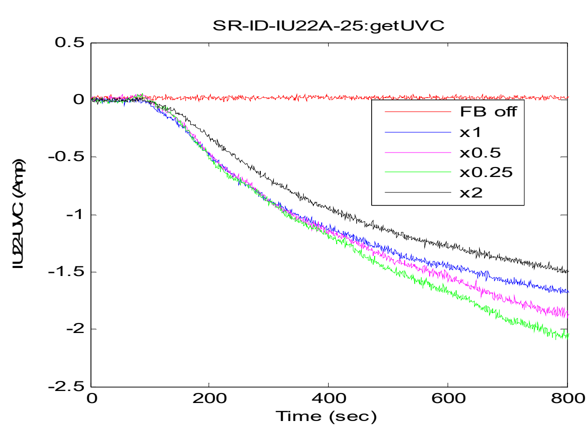

Figure 9: The corresponding corrector strength variations for different Ki coefficient of Fig. 8.

Real Beam Test for Local XBPM Feedback

Based on the introduced simulated orbit drift method, we could obtain the proper and optimal configurations for the XBPM local feedback efficiently and then applying them

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to the real beam in the TPS. Figure 10 and 11 shows the promising results of the BPM/XBPM drift suppression when applying the XBPM local feedback. The BPM included in XBPM local feedback loop could be further controlled smaller than submicron from 1~2 um. XBPM position drift could be also decreased from 10~14 um to 2 um.

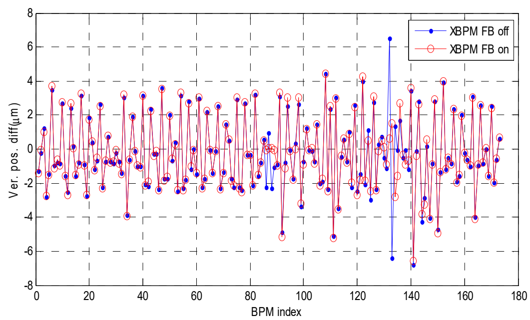

Figure 10: The overall BPM orbit drift comparison between XBPM local feedback on and off. The BPM position drift could be suppressed lower than submicron when the assigned BPM (BPM index 86-88) included in the feedback loop.

CONCLUSION

The long-term position stability observed from electron BPM and XBPM is presented. The major concern from users is the orbit drift would remain 1~3 hours at different ranges for different beamline after beam dump and restored. As beam dump longer, the drift become larger and longer. Therefore, the local XBPM feedback is proposed and tested to improve the orbit drift. A simulated orbit drift by changing BPM/XBPM offset is introduced to speed up test time and applying for comparisons of different configurations for a controlled conditions. The results of real beam test shows excellent drift suppression effect.

REFERENCES

[1] Pei-Chen Chiu, et al., "Fast Orbit Scheme and Implementation for TPS", in *Proc. 4th Int. Particle Accelerator Conf. (IPAC'13)*, Shanghai, China, May 12-17 2013, pp. 1146-1148.

[2] Pei-Chen Chiu, et al., "Orbit Correction with Path Length Compensation Based on RF Frequency Adjustments in TPS", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, ,Copenhagen, Denmark, May 14-19 2017, pp. 1553-1555. doi:10.18429/JACoW-IPAC2017-TUPAB103

[3] J. Morse, *et al.*, "Diamond X-ray beam-position monitoring using signal readout at the synchrotron radiofrequency", *J. Synchrotron Rad.* 17, 456-464 (2010)

[4] D. Shu, *et al.*, "Development of an x-ray beam position monitor for TPS EPU beamline front ends", *J. Phys.: Conf.* **425**, 042003 (2013).

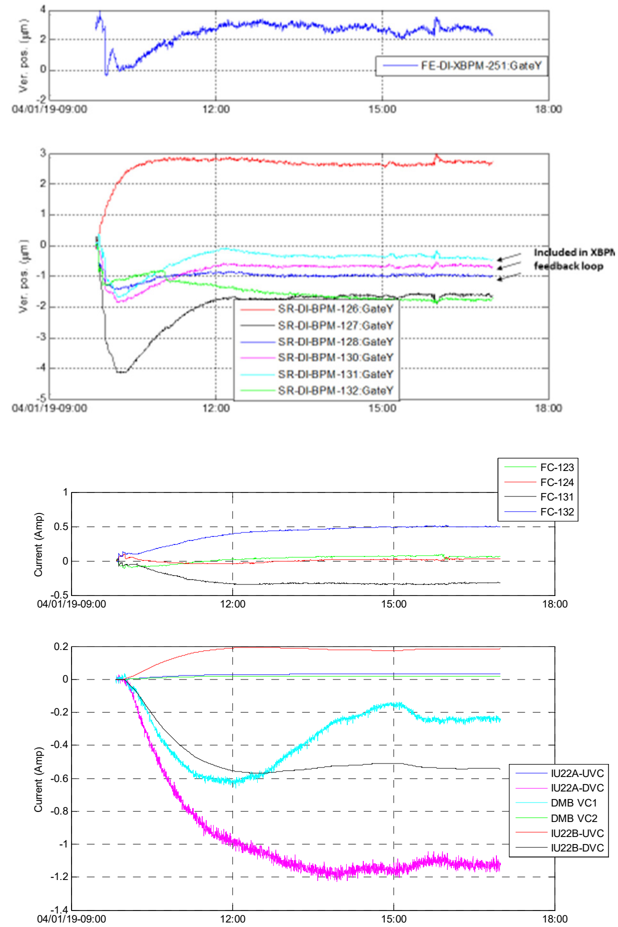

Figure 11: The upper plotis BPM/XBPM position drift when applying XBPM local feedback. The BPM drift included in the feedback loop is much smaller than those excluded in the loop. XBPM drift is also decreased from 10~14 um to 2 um. The lower plot is the fast correctors (FOFB) and ID correctors (XBPM local feedback) strength variations.